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(56) Documents cited
GB 1526343 A GB 1351227 A GB 1241776 A
US 3810081 A

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(54) **Alarm system for monitoring the anchorage condition of a vessel**

(57) An anchor alarm system for monitoring the anchorage condition of a vessel comprising a load cell and control box which continually measures the anchor cable 3 tension, stores in memory the maximum tension experienced during the anchoring procedure (the anchor setting tension), compares subsequent anchor cable tension with this anchor setting tension, or some other preset tension, and drives a warning signal output or alarm when the actual anchor cable tension exceeds the anchor setting tension or other preset tension.

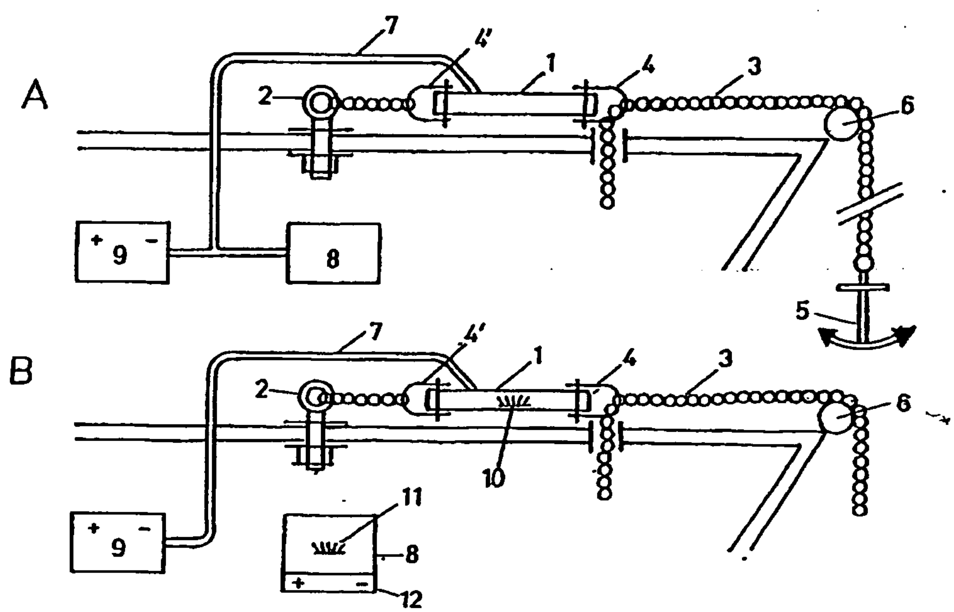

FIGURE 7

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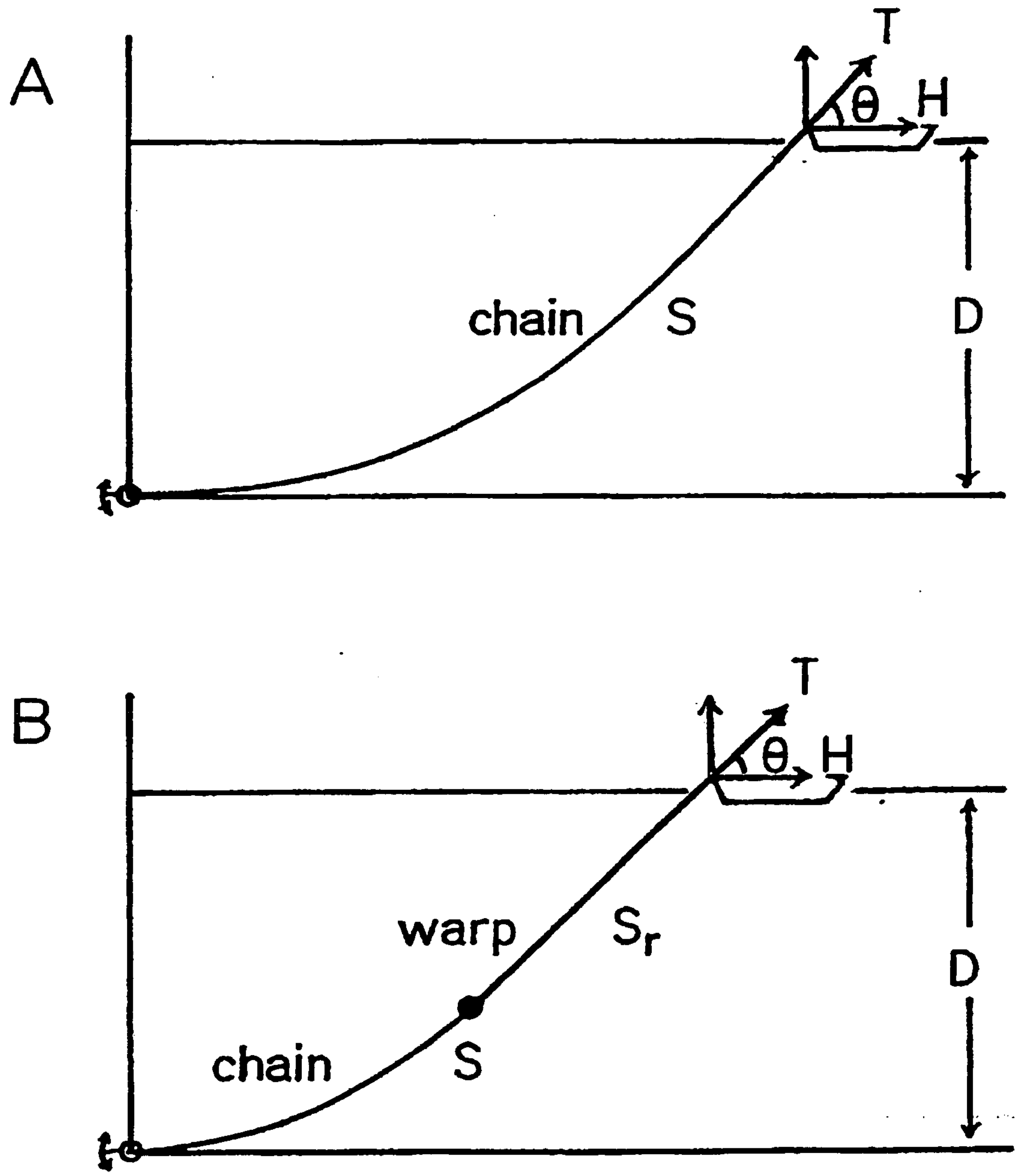


FIGURE 1

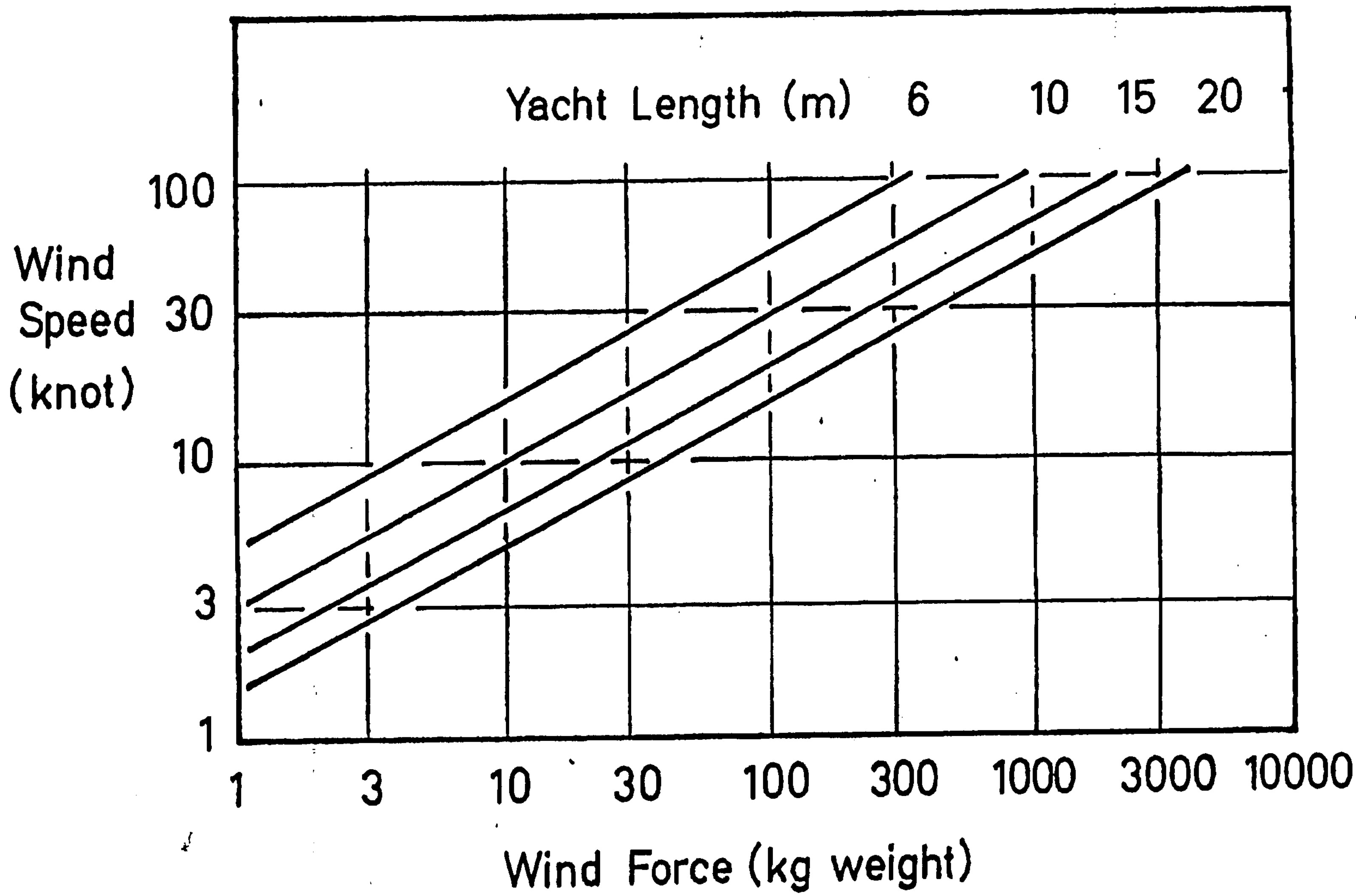

Yacht Length (m)
6
10
15
20
Wind
Speed
(knot)
100
30
10
3
1
1
3
10
30
100
300
1000
3000
10000
Wind Force (kg weight)

FIGURE 2

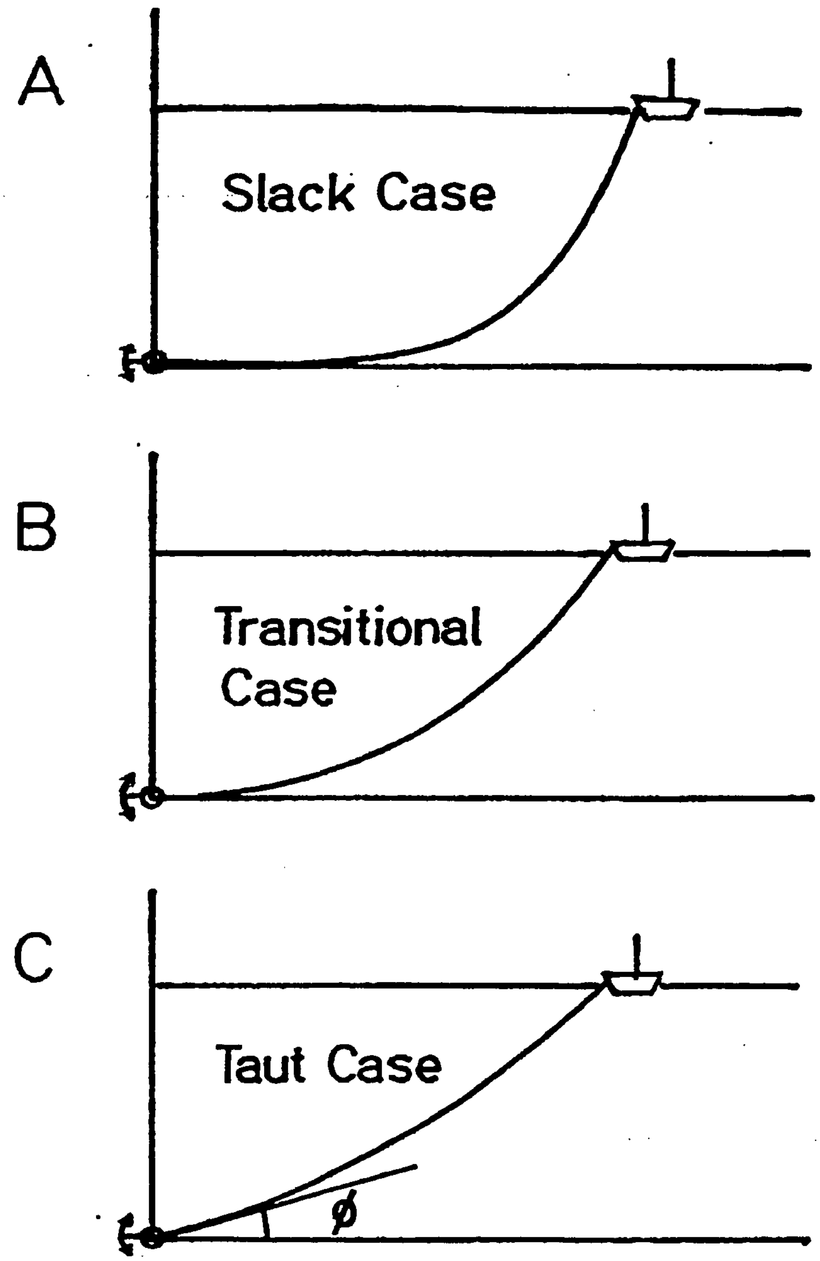


FIGURE 3

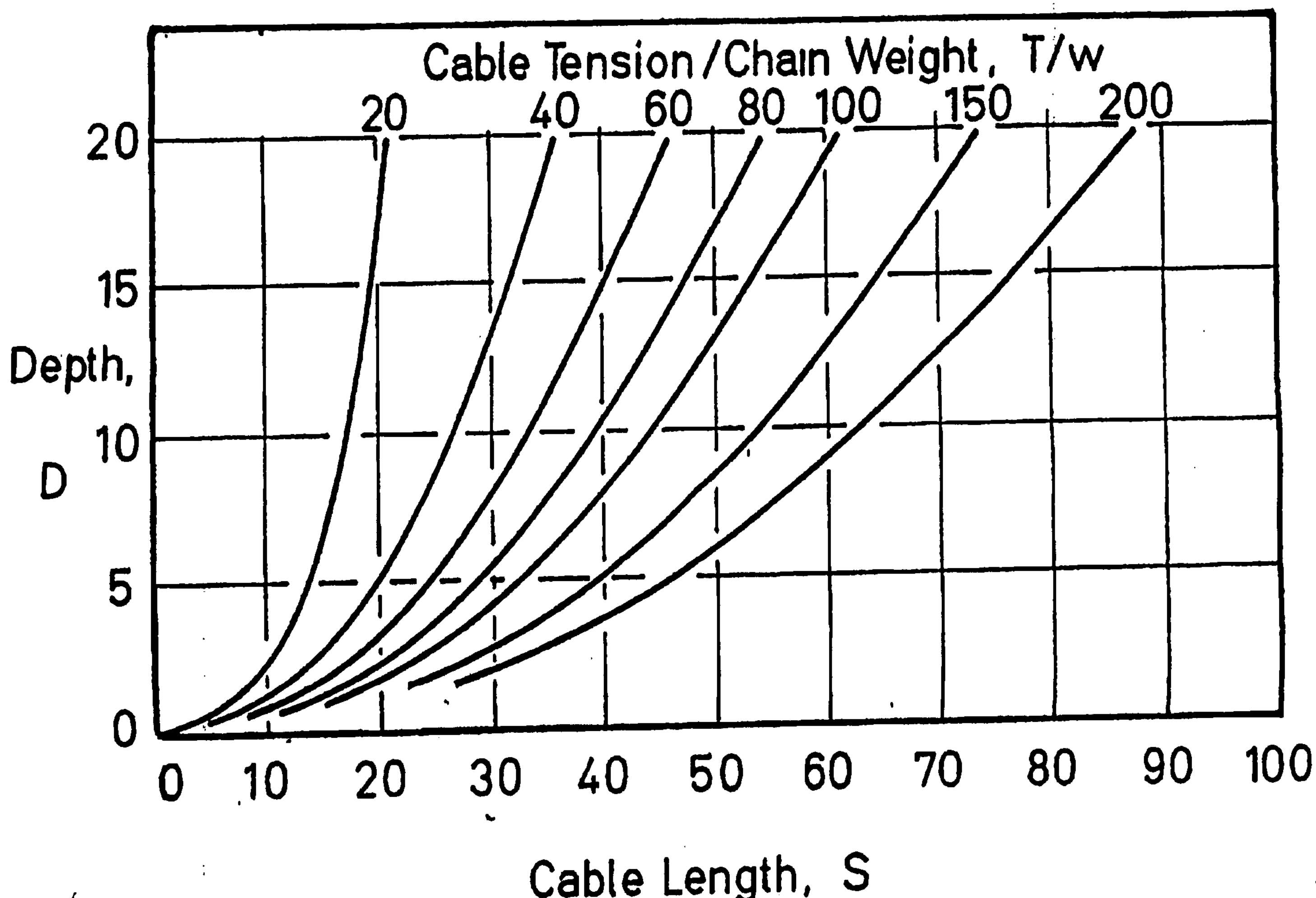
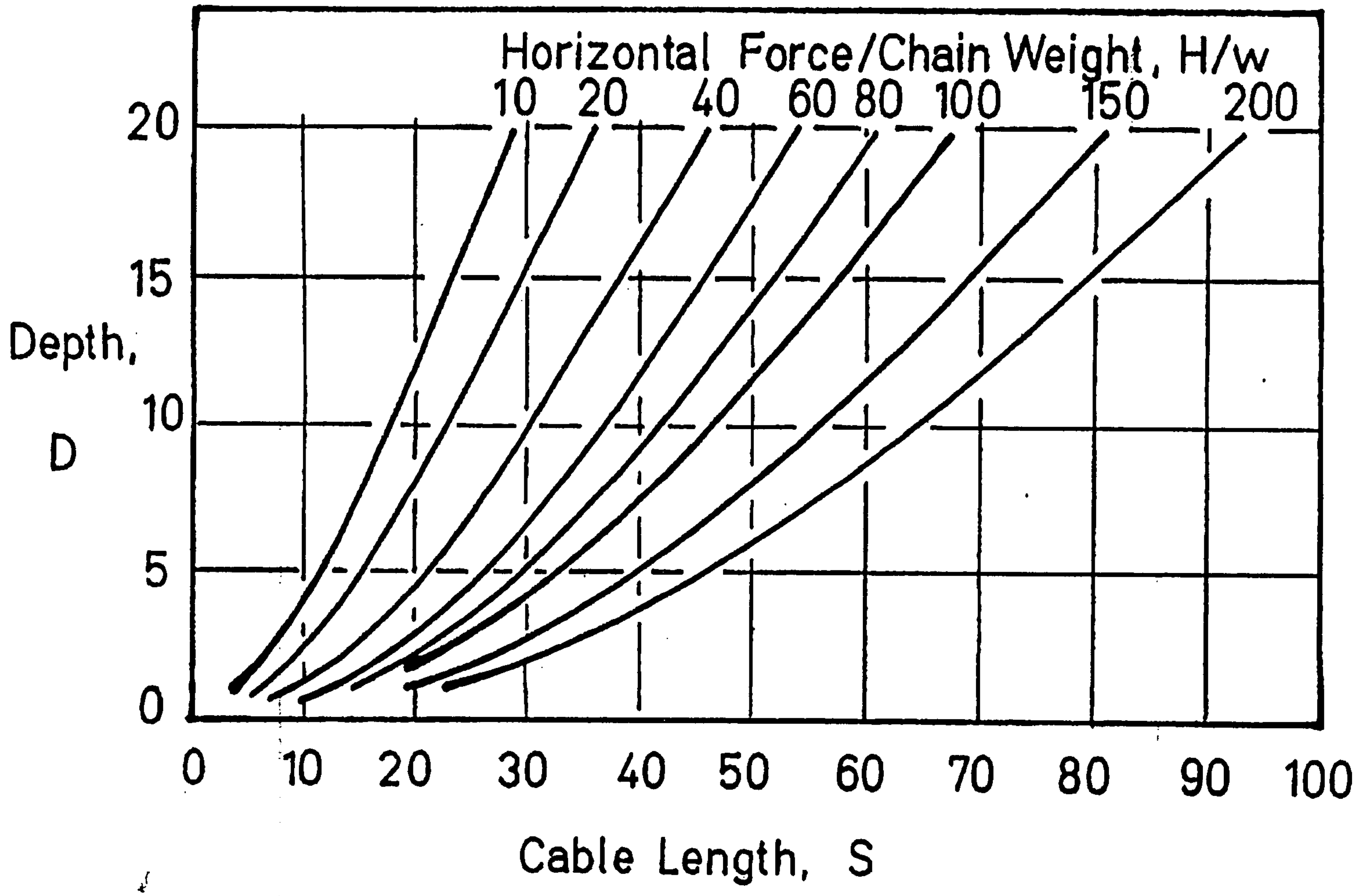

Cable Tension / Chain Weight, T/w
20
40
60
80
100
150
200
Depth, D
0
5
10
15
20
0
10
20
30
40
50
60
70
80
90
100
Cable Length, S

FIGURE 4



Horizontal Force/Chain Weight, H/w
10
20
40
60
80
100
150
200
Depth, D
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Cable Length, S

FIGURE 5

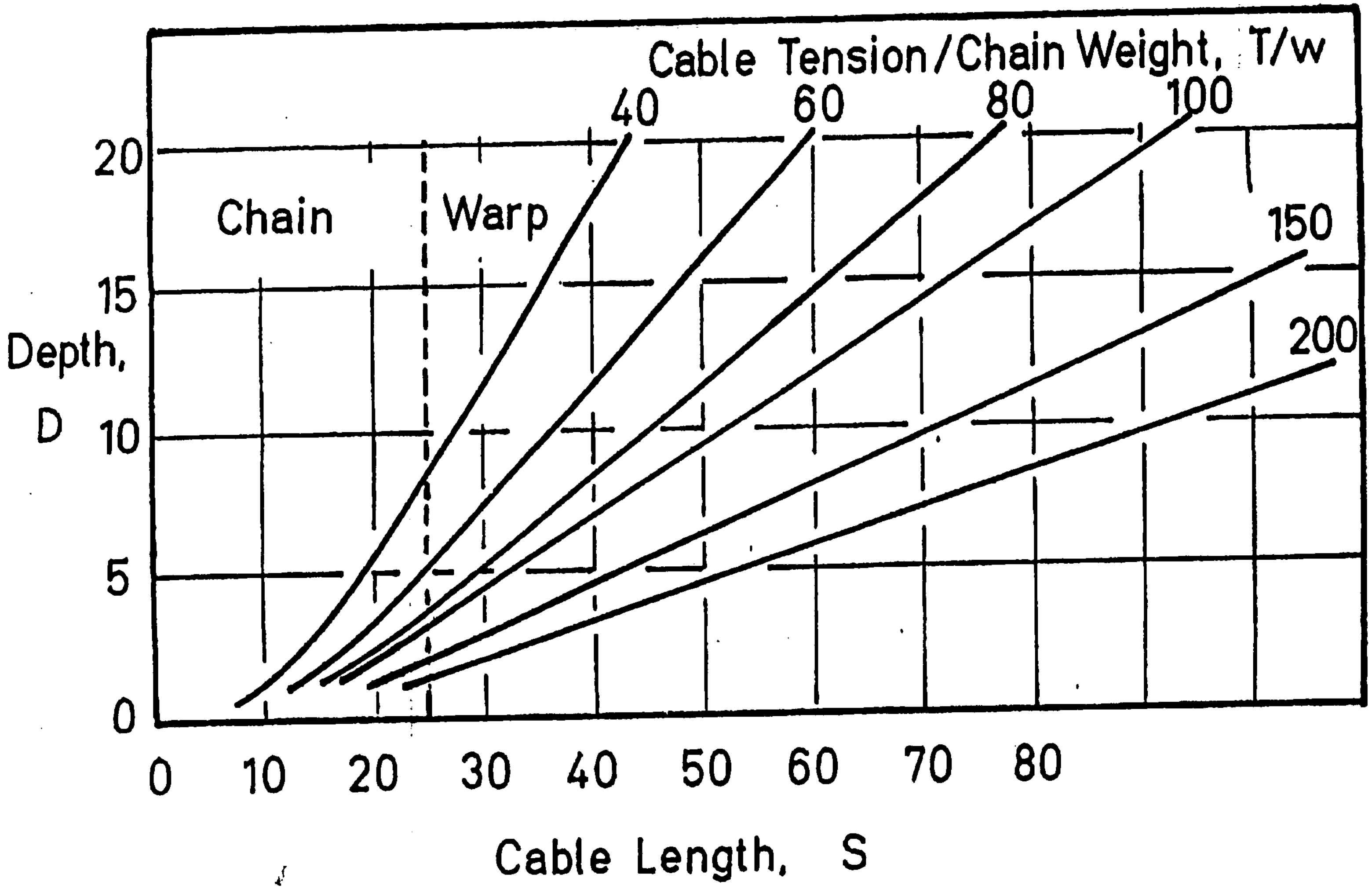

Cable Tension/Chain Weight, T/w
40
60
80
100
150
200
Chain
Warp
Depth, D
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Cable Length, S

FIGURE 6

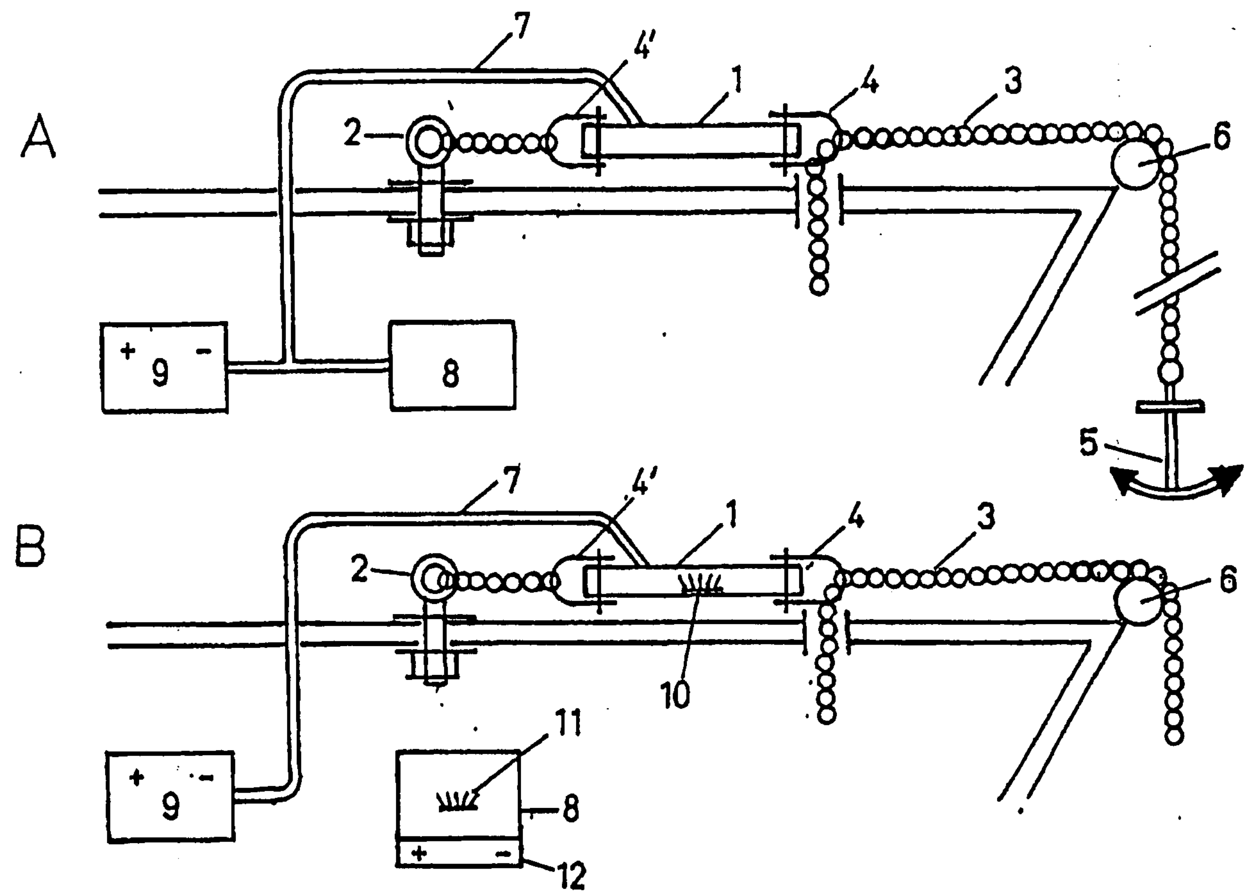


FIGURE 7

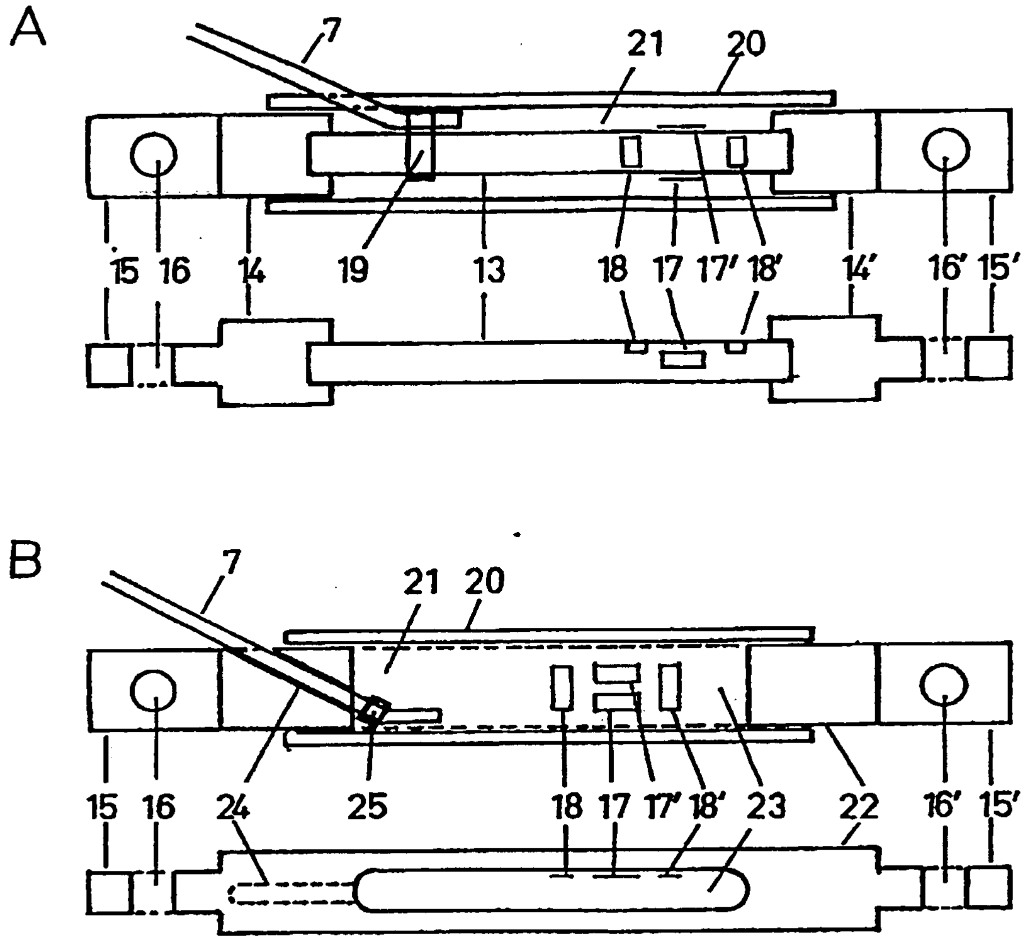

A
7
21
20
15
16
14
19
13
18
17
17'
18'
14'
16'
15'
B
7
21
20
15
16
24
25
18
17
17'
18'
23
22
16'
15'

FIGURE 8

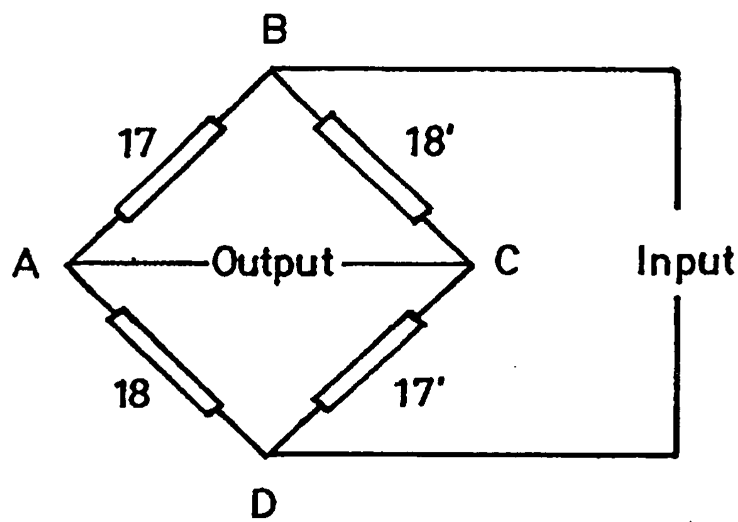


FIGURE 9

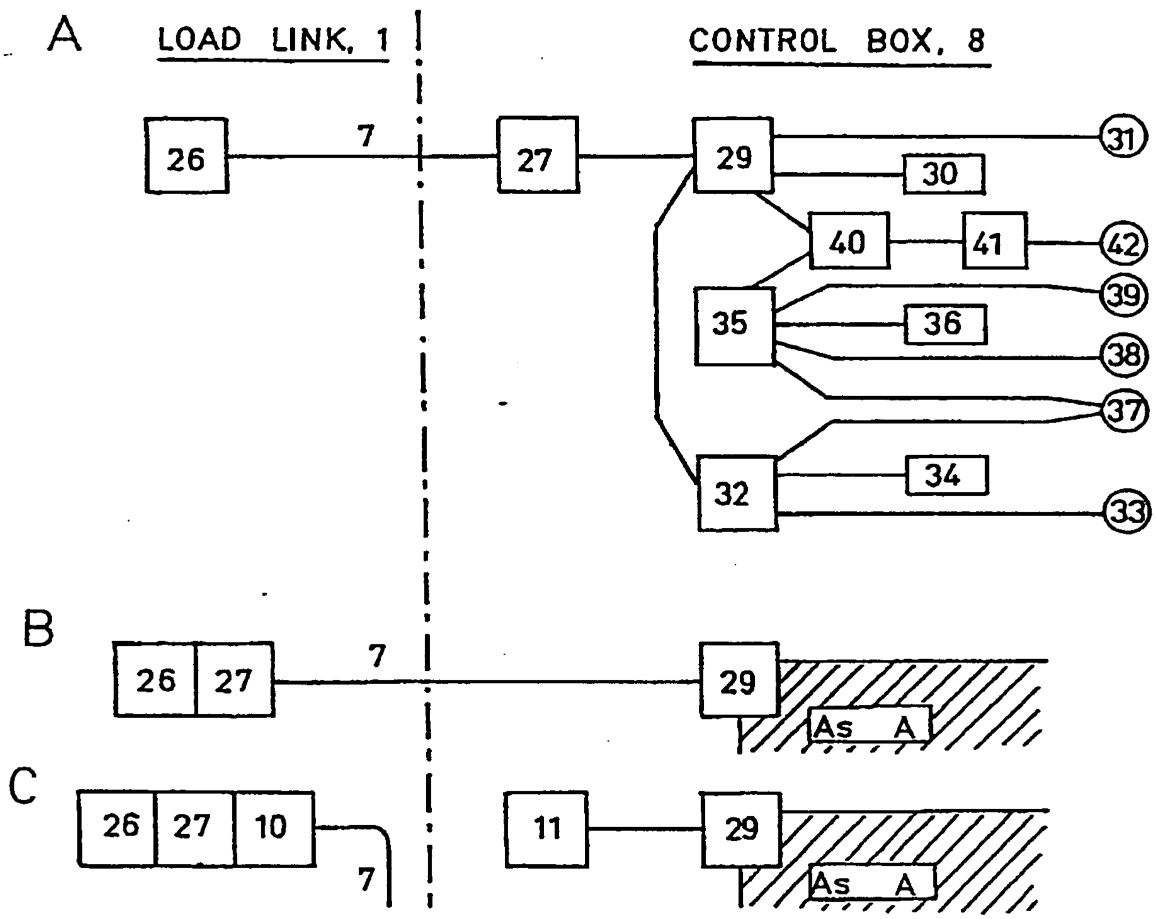

A
LOAD LINK, 1
CONTROL BOX, 8
26
7
27
29
31
30
40
41
42
35
39
36
38
37
32
34
33
B
26
27
7
29
As A
C
26
27
10
7
11
29
As A

FIGURE 10

ALARM SYSTEM

The present invention relates to an anchor alarm system for monitoring the anchoring condition of a small vessel.

Whereas the procedure of anchoring of a small marine craft, vessel or yacht, and its security when anchored are of critical importance to the vessel and its crew, the procedure of anchoring is generally carried out with no more than a qualitative knowledge of important factors such as the holding power of the ground tackle and the stresses likely to be imposed upon it by rising wind or change of tide. Accordingly the security of an anchored vessel relies largely upon the experience and seamanship of the skipper.

The type of vessel to which the present invention is particularly applicable will be either a sailing yacht equipped with an auxiliary engine, or a motor yacht. Typically the invention will be useful for such vessels whose lengths lie in the range 6 to 20 metres, although its use with smaller or larger vessels is not excluded. A typical procedure when anchoring such a vessel would involve the following stages:

(i) Selection of Location: skipper chooses a suitable anchorage with an appropriate depth of water after allowing for any rise and fall of tide which will occur.

(ii) Assessment of Nature of Bottom: skipper assesses the nature of the sea bottom and selects a spot in the anchorage where the bottom is relatively free from weed, stone and obstructions. Helmsman stops the yacht at anchoring position.

(iii) Lowering Anchor: crew member lowers the anchor over the bow roller until it reaches the bottom, and signals accordingly to the helmsman.

(iv) Laying out the cable: helmsman backs off the vessel slowly under engine (or sometimes sail) and crewman pays out the anchor cable until the desired length has been deployed.

(v) Setting Anchor: helmsman allows the anchor to settle and gently backs off again to drive the anchor into the sea bed thereby setting the anchor.

(vi) Checking Anchor Holding: anchor holding is checked by increasing the engine power (or by sailing) while helmsman observes a suitable transit on land to establish that the vessel remains stationary while pulling hard on the anchor. At the same time bow crewman holds the cable to ascertain whether it tightens fully and whether it jerks, the latter indicating anchor dragging. Crewman finally signals helmsman if he considers all well.

While all these stages are important it is the last two which are crucial to safety. What is lacking in the standard procedure described above, is any measurement (other than qualitative) of the actual tension on the anchor cable. Lacking this knowledge it is commonplace for questions such as the following to arise: "If the wind rises will the tension on the cable be too great and will the anchor drag or even pull out altogether? How strong will the wind have to be before the anchor begins to drag? If the vessel is anchored in a seaway and snatching at its anchor cable, will the snatching load be sufficient to pull the anchor out? Should more cable be let out, and if so how much?" With current anchoring techniques, such questions are answered by a skipper's experience and general seamanship. They are never answered on the basis of quantitative measurement.

It is an object of the present invention to remove or at least mitigate one or more of the above disadvantages, and to provide clear solutions to some or all of the above problems. According to the method of the invention, quantitative measurement of the tension on an anchor cable is made more or less continuously, and the results of such measurement are used to alert crew to the occurrence of an overload of the anchor system, which could be dangerous to a vessel's safety.

While it is our contention that the key to safe anchoring of a small vessel is the measurement and understanding of the forces involved, relevant information is not widely available, nor is it to be found assembled in a readily accessible place. Accordingly, for the purpose of explaining the scope and purpose of the present invention, it is necessary to outline the key factors which are relevant to the anchoring of a small vessel. This may be done with reference to the following drawings in which:

Figure 1: illustrates the various parameters relevant to a vessel anchored with (A) chain cable and (B) cable consisting of chain and warp

Figure 2: shows the dependence of the wind resistance of a small vessel upon its length and the wind velocity.

Figure 3: shows various dispositions of the anchor cable of an anchored vessel.

Figure 4: shows the dependence of the length of cable required for the"Transitional Case", upon depth of water for various anchor cable tensions, T, using all-chain cable.

Figure 5: shows a similar dependence for different horizontal forces at the stem head of the vessel, H.

Figure 6: shows the dependence of the length of cable for the "Transitional Case", upon the depth of water for different anchor cable tensions using a cable consisting of 25 metres of chain coupled to warp.

Figure 1(A) shows a vessel anchored with uniform chain cable, and in Figure 1(B) a vessel anchored with an anchor cable consisting of chain and neutral density warp. In Figure 1(A) the chain follows a curve called a catenary, while in Figure 1(B) the chain follows a catenary, but the warp, being of neutral density, is straight. In each case, the water depth is denoted by D, the length of chain by S, and the length of the warp by S_r. Each vessel experiences a horizontal force, H, due to wind and tide, and this, combined with the weight of the chain, generates a tension, T, in the anchor cable. The three features which can be assessed quantitatively, and which affect the safety of the anchored craft are:

(1) The holding power of the anchor on the sea bed.

(2) The magnitude of the horizontal force on the hull of the vessel resulting from wind, waves and current.

(3) The angle between the cable and the sea bed at the anchor, and the force required to lift the anchor cable above the horizontal at the anchor.

The theory and experimental data relevant to these three aspects of anchoring are outlined in the sections which follow.

(1) The holding power of anchors.

Relatively few quantitative experiments have been conducted on the holding power of anchors, and the experimental conditions have been somewhat specialised. For example Alain Gree in a book entitled "Anchoring and Mooring" (Publ Adlard Coles Ltd and William Collins Ltd, London 1981) describes experiments in which yacht anchors weighing about 12 kg were set in sand under water and dragged by means of a tractor on a beach at a constant rate of between 0.1 and 0.2 metres per second. The tension on the cable was measured by a mechanical spring balance. These tests showed that well designed plough anchors, for example CQR and Bruce anchors, exhibited a continuous holding power of between 300 and 500 kg even as they dragged. By contrast, most Danforth, and Brittany-type anchors (termed "ancres bascule" in French) behaved cyclically although they had maximum holding powers in the same range. When these anchors were dragged as described above, the tension on the cable rose gradually to a maximum and then dropped suddenly as the anchor pulled out, the

tension then built up again to the maximum value, whereupon the anchor pulled out again and the cycle was repeated. Some anchors showed very low holding powers. Tests carried out using the current invention gave comparable results. Thus a 7 kg CQR plough anchor showed no tendency to drag when pulled by a force up to 300 kg, while a 7 kg Danforth anchor showed no tendency to drag when pulled by a force up to 160 kg, but pulled out when the force was increased further, and then re-bedded itself on re-tensioning the cable, confirming the cyclic behaviour previously noted by Gree.

The values of anchor holding power obtained in the tests reported by Gree and ourselves are summarised in Table 1

TABLE 1

HOLDING POWER OF ANCHORS IN TRACTION TESTS

MODEL	MATERIAL (NOTES)		WEIGHT (kg)	HOLDING POWER (kg) MAX	MIN	SOURCE
"PLOUGH" ANCHORS						
CQR	STEEL	(a)	11	500	420	GREE
CQR	STEEL		7	300	na	THIS WORK
BRUCE	STEEL	(a)	10	300	210	GREE
"BASCULE" ANCHORS						
DANFORTH	STEEL	(b)	7	160	50	THIS WORK
BRITTANY MK 2	STEEL	(a)	12	560	380	GREE
FOB-HP	STEEL	(b)	12	320	30	GREE
LIGHT BRITTANY	ALLOY	(c)	7	920	740	GREE

NOTES:
(a) These anchors showed a more or less constant high resisting force when dragged at 0.1 to 0.2 m/s under the test conditions.
(b) These anchors behaved in a cyclic manner when dragged.
(c) The enormous holding power of this anchor is explained by the fact that it is made of a low density alloy, and so is much larger than the steel anchors of the same weight. This indicates that the holding power of an anchor is related more to its geometrical size than to its weight.

The dependence of holding power of yacht anchors upon the angle of pull has been less well studied but the evidence from studies with large anchors indicates that their holding power is reduced to 60-70% when the angle of pull is as little as 6 degrees above horizontal, and to 40-50% when the angle of pull is as little as 12 degrees above the horizontal. Similar results probably apply to small anchors. Evidently, to be effective, any anchoring system should be configured so that the chain at its attachment to an anchor is either horizontal or does not rise more than a few degrees above the horizontal under maximum load.

(2) Horizontal forces experienced by a hull due to wind and current

The average pressure on an object (that is the force on the object divided by its frontal area) positioned in an infinitely extended flowing fluid, depends not only upon the fluid velocity, but also upon the shape of the object and upon whether the flow

is streamlined or turbulent. The average pressures on differently shaped objects can be referred to that on a uniform cylinder, whose axis is perpendicular to the direction of fluid flow, by means of a drag coefficient. For boat hulls the drag coefficient is generally taken as 0.70 (that is a hull experiences 70% of the force experienced by a cylinder having the same projected area). The force, F, due to air flow past a yacht is proportional to the square of the wind velocity, V, and the combined frontal area, A, of the hull, mast, rigging, superstructure, etc.

Table 2 shows the way in which the different parts of a sailing yacht contribute to the overall area which it exposes when headed directly into wind.

TABLE 2

CONTRIBUTION OF VARIOUS PARTS OF A SAILING YACHT TO FRONTAL AREA

BOAT LENGTH (metre)	6	8	10	12	15	20
	CONTRIBUTION TO FRONTAL AREA (sq metre)					
HULL	1.9	3.4	5.3	7.6	12.0	21.3
MAST	0.4	0.8	1.2	1.7	2.6	4.7
SAIL (FURLED)	0.1	0.1	0.2	0.3	0.4	0.6
RIGGING	0.1	0.2	0.4	0.6	0.9	1.6
MISCELLANEOUS	0.3	0.5	0.8	1.1	1.7	3.0
TOTAL AREA	2.8	5.0	7.9	11.3	17.6	30.2

The figures are based upon those given by Gree for an 8 metre yacht, and are scaled in proportion to the square of the length of the yacht for yachts between 6 and 20 metres long. The total exposed area is given by the formula of Equation (1)

$$A/(m^2) = 0.08\ (L/m)^2 \qquad \text{Equation (1)}$$

Again, following Gree, the force on a vessel due to wind is given approximately by Equation (2)

$$F/(kg) = 0.012 \times A/(m^2) \times (V/knot)^2 \qquad \text{Equation (2)}$$

Combining equations (1) and (2) gives Equation (3)

$$F/(kg) = 9.6\times10^{-4} \times (L/m)^2 \times (V/knot)^2 \qquad \text{Equation (3)}$$

For the sake of simplicity we approximate equation (3) by Equation (4)

$$F/kg = (L/m)^2 \times (V/knot)^2/1000 \qquad \text{Equation (4)}$$

Table 3 gives values for wind resistance, F, as a function of boat length, L, and wind speed, V, according to Equation (4).

TABLE 4

DEPENDENCE WIND RESISTANCE UPON WIND SPEED FOR YACHTS OF DIFFERENT LENGTHS

BOAT LENGTH (metre)	6	8	10	12	15	20
WIND SPEED (knot)			WIND RESISTANCE (kg)			
5	1	2	3	4	6	12
10	4	6	10	14	22	40
15	8	14	22	32	50	88
20	14	26	40	58	90	160
30	32	58	90	130	200	360
40	58	100	160	230	360	640
50	90	160	250	360	560	1000
60	130	230	360	520	810	1440
80	230	410	640	920	1440	2560
100	360	640	1000	1440	2250	4000

Figure 2 gives illustrative plots of wind drag for sailing yachts of different lengths as a function of wind speed.

The force of resistance to flow of water, F_{aq}, depends upon the hull design, and individual boat designers must be consulted for precise figures. However, for speeds, V_{aq}, below the maximum hull speed, the square law applies and figures given by Gree accord with the approximate relationship given in equation (5)

$$F_{aq}/kg = (L/m)^2 \times (V_{aq}/knot)^2/50 \qquad \text{Equation (5)}$$

Typically critical wind speeds will be in the region of 50 knot

while tidal flow rates are unlikely to exceed 5 knot in any area where a vessel is likely to anchor. Taking these two values as a minimum amd maximum respectively, the wind drag, F, under minimal critical conditions will be five times the water drag, F_{aq}, under the maximal limiting condition. Thus in calculating the horizontal force under extreme conditions, high wind speed will always be the dominant factor rather than high water speed. Accordingly, in what follows, only the force arising from wind on hull and rigging will be considered as relevant to anchoring safety.

(3) The catenary curve, angle of the chain to the sea bed, and forces involved.

The symbols used in this section, which are illustrated in Figures 1 and 3, are defined as follows:

S = Length of the part of the cable comprising chain

S_r = Length of the part of the cable comprising warp

S_{tot} = Total length of cable = $S + S_r$

w = Weight per unit length of chain, alternatively called "chain weight". For neutral density warp w is taken as zero.

D = Depth of water at the anchor.

H = Horizontal force on hull due to wind and current

T = Tension on cable at stemhead of yacht

θ = Angle of cable to horizontal at stemhead of yacht

ϕ = Angle of chain to horizontal as it leaves anchor

Figure 3 shows three possible situations when a vessel is subject to a horizontal force (for example due to wind or tidal flow) and is anchored by uniform chain cable. In all cases the segment of the chain which does not lie on the sea bed will take the form of a curve called a catenary. In Figure 3(A) the horizontal force is relatively small and much of the chain lies on the sea bed. Any pull on the anchor is exerted horizontally. This is called the "Slack Case". In Figure 3(B) the horizontal force on the hull is somewhat greater and the chain is just horizontal at the anchor, but none lies on the sea bed: the catenary curve is tangential to the horizontal at the anchor. The pull on the anchor is still exerted horizontally. This is called the "Transitional Case". In Figure 3(C) the chain leaves the anchor at a finite angle, ϕ, to the sea bed. The pull on the anchor is now from an angle above the horizontal. This is called the "Taut Case". As has been noted under section (1) above, the holding power of an anchor is highest when the cable pulls horizontally and decreases substantially when the pull is at even a small angle above the horizontal. The Transitional Case sets a limit

beyond which the situation of an anchored vessel becomes increasingly dangerous. Accordingly the following treatment deals only with the "Transitional Case".

The mathematical equations associated with the catenary are well known, and readily available, for example in the book by Margenau and Murphy entitled "Mathematics of Physics and Chemistry" (publ McGraw Hill Book Co., New York, 1941). Those relevant to the current consideration of the "Transitional Case" are as follows:

Horizontal Force, $H/w = (S^2 - D^2)/2D$ Equation (6)

Tension on Cable, $T/w = (S^2 + D^2)/2D$ Equation (7)

also, $T/w = H/w + D$ Equation (8)

Angle of Chain to horizontal at stem head, θ:

$\tan\theta = S \times w/H$ Equation (9)

$\sin\theta = S \times w/T$ Equation (10)

Typical weights of chain per unit length, w, working loads and breaking loads are given in Table 4.

TABLE 4

APPROXIMATE CHARACTERISTICS OF ANCHOR CHAINS

DIAMETER, d (inch)	(mm)	WORKING LOAD (kg)	BREAKING LOAD (kg)	WEIGHT PER METRE (kg per metre)
1/4	6.5	1000	2000	1.0
5/16	8	2000	4000	1.5
3/8	9.5	3000	6000	2.4
7/16	11	4500	9000	3.2
1/2	13	6000	12000	4.2

NOTE: to a rough approximation the weight of chain, w, is given by: $(w/\text{kg m}^{-1}) = 16(d/\text{inch})^2 = 0.025(d/\text{mm})^2$

Table 5 lists the lengths, S, of uniform chain required to hold against various anchor cable tensions, T, in various depths of water, D, where the weight per unit length of chain is w. Table 6 show analogous data for the horizontal force H. The units of these quantities must be self consistent: thus if the tension, T, (or horizontal force, H) is in kilograms, the chain length, S, and water depth, D, in metres, then the weight per unit length of chain must be in kilograms per metre. Alternatively if T and H were in pounds and S and D in fathoms, then the weight chain weight per unit length, w, would need to be in pounds per fathom.

TABLE 5

LENGTHS OF CHAIN CABLE REQUIRED IN THE TRANSITIONAL CASE FOR STATED CABLE TENSIONS AS A FUNCTION OF DEPTH OF WATER

DEPTH, D	CABLE TENSION/CHAIN WEIGHT, T/w									
	10	20	30	40	50	60	80	100	150	200
	CABLE LENGTH, S									
2	6	9	11	12	14	15	18	20	24	28
3	7	11	13	15	17	19	22	24	30	35
4	8	12	15	17	20	22	25	28	34	40
5	9	13	17	19	22	24	28	31	38	44
7	10	15	19	23	26	28	33	37	45	52
10	10	17	22	26	30	33	39	44	54	62
12		18	24	29	32	36	42	47	59	68
15		19	26	31	36	40	47	53	65	76
20		20	28	35	40	45	53	60	75	87

TABLE 6

LENGTHS OF CHAIN CABLE REQUIRED IN THE TRANSITIONAL CASE FOR STATED HORIZONTAL FORCE AS A FUNCTION OF DEPTH OF WATER

DEPTH, D	HORIZONTAL FORCE/CHAIN WEIGHT, H/w									
	10	20	30	40	50	60	80	100	150	200
	CHAIN LENGTH, S									
2	7	9	11	13	14	16	18	20	25	28
3	8	11	14	16	18	19	22	25	30	35
4	10	13	16	18	20	22	26	29	35	40
5	11	15	18	21	23	25	29	32	39	45
7	14	18	22	25	27	30	34	38	46	53
10	17	22	26	30	33	36	41	46	56	64
12	20	25	29	33	37	40	45	50	61	70
15	23	29	34	38	42	45	51	57	69	79
20	28	35	40	45	49	53	60	66	80	92

Figures 4 and 5 show graphs of the lengths of chain required to achieve the Transitional Case for various cable tensions and horizontal forces respectively as a function of depth.

It is often useful to use a combination of chain and warp where a length of chain, S, is attached to the anchor and a length of warp S_r, connects the chain to the yacht. Essentially this saves weight. With adequate length of chain and warp it is still possible to ensure that the chain remains horizontal at the point where it is attached to the anchor. The relevant relation between depth of water, D, cable tension, T, chain length S, warp length S_r, and weight of chain per unit length, w, assuming that the weight per unit length of the warp is negligible, is given by equation (11)

$$D = (T/w) - \{(T/w)^2 - S^2\}^{1/2} + S \times S_r (w/T) \quad \text{Equation (11)}$$

The corresponding relationship involving the horizontal force, H, is given by equation (12):

$$D = -(H/w) + \{(H/w)^2 + S^2\}^{1/2} + S \times S_r (w/H) \quad \text{Equation (12)}$$

Figures 6 illustrates the case where the chain length is 25 units and shows, for the Transitional Case, the total length of chain plus warp, S_{tot} (= $S + S_r$), as a function of water depth, D, for

various tensions, T. It may be noted that the lines representing the dependence of D upon S for a given T are simple tangential extensions from the point on the relevant curve for chain corresponding to a chain length of 25 metres. The corresponding curves showing depth against cable length for different values of the horizontal force, H/w, (Equation (12)), become increasingly close to those in Figure 6 when H/w exceeds about 40.

For the purpose of illustration, the above information may be usefully applied to a 10 metre yacht equipped with a 15 kg CQR anchor attached to at least 25 metres of 3/8" (9.5 mm) chain along with warp as required.

It is first noted that the forces involved in anchoring under severe conditions are very large even for a 10 metre yacht, and cannot easily be assessed by the conventional method of placing a hand on the anchor cable to determine whether it is sufficiently taut. For example the force experienced in a 50 knot wind would be 250 kg and in a 60 knot wind 360 kg. Such forces are nevertheless well within the holding power of a 15 kg plough or Danforth anchor which is properly bedded. However if an anchor is to hold under severe conditions good bedding cannot simply be

assumed. Ideally it should be tested by establishing an acceptable anchor cable tension. Very often when anchoring the nature of the bottom is unknown and assessing the holding power of the anchor is not easy. The only sure way to test whether the anchor is holding is to measure the load on it and check that it does not drag under some specific load which is considered to be acceptable. Particularly when an anchor is laid in kelp its holding power is known to be poor, and the holding unreliable.

From section (3) it is evident that adequate cable tension can readily be maintained by an anchor chain before it lifts from the sea bed at the anchor (i.e. in the Transitional Case), provided that enough cable is let out, and provided that the chain is of sufficient weight per unit length. Thus for a 10 metre yacht fitted with 3/8" chain, anchored in a depth of 10 metres, 46 metres of chain will provide a horizontal force of 240 kg, adequate for a wind speed of 50 knots, while 56 metres will provide 360 kg, adequate for a wind speed of 60 knots. If the yacht is equipped with 25 metres of 3/8" chain and then warp the total lengths of cable required in the two cases becomes 52 metres, and 72 metres respectively. In each case the lengths of cable are substantial and correspond to anchoring scopes (chain length divided by depth) of more than five, well above the figure

of three so often quoted in the yachting literature.

Evidently quantitative measurement of anchor cable tension and anchor holding can enable a more confident assessment to be made of safety in any anchoring situation. Specifically, an assessment of the wind speed likely to be encountered while at anchor directly provides a figure for the anchor loading likely to be experienced, and reference to a simple equation or table enables calculation of the appropriate length of anchor cable which should be deployed. Subsequently, by continually monitoring the actual tension, and comparing it with the maximum safe tension, a skipper can make a confident assessment of the safety of his anchored yacht.

Accordingly, the present invention provides an anchor alarm system suitable for use in monitoring the anchorage condition of a vessel, which system comprises load cell means provided with mechanical coupling means for connection of the load cell means, in use of the system, in-line with an anchor cable means of a vessel, said load cell means being provided with signal transmission means for transmissison, in use of the system, of a signal related to the tension to which said load cell means is subjected, to a control system having a processor means, memory

means, and warning signal output means, said processor means being formed and arranged for receiving anchor cable tension signals from said load cell means, storing data in said memory means corresponding to a maximum anchor cable tension signal corresponding in turn to an anchor-setting tension on said anchor cable experienced during an immediately preceding time interval, in a set-up mode of the control system, comparing subsequent anchor cable tension signals with data stored in said memory means so as to detect at least anchor cable tensions greater than said anchor-setting tension or some lesser preset alarm-triggering tension, in a monitoring mode of the control system, and driving said warning signal output means in response to detection of such greater anchor cable tensions, in an alarm mode of the control system.

Thus with an alarm system of the present invention, a vessel's crew may be readily alerted to situations in which the integrity of the vessel's anchorage may be threatened.

A further aspect the present invention provides a method of monitoring the anchorage condition of a vessel comprising the steps of recording an initial maximum anchor cable tension

corresponding to an anchor-setting tension, monitoring anchor cable tension thereafter and comparing it with said anchor-setting tension or some lesser preset tension, and generating a warning signal output at least when the anchor cable tension exceeds said anchor-setting tension or alternate preset alarm-triggering tension.

As used herein the expression anchor cable indicates any flexible elongate member used for connecting a vessel to its anchor including chain and rope and any combination thereof. The load cell may be coupled either directly in-line with the anchor cable, for example between separate sections of the anchor cable, or between the vessel and one end of the anchor cable, or between the vessel and some point within the length of the anchor cable. Alternatively the load cell may simply be coupled between different parts of a single section of the anchor cable by mechanically short circuiting a loop of anchor cable. Any suitable mechanical coupling means may be used including, rope, chain, clamping means and releasable fasteners and any combination thereof. Conveniently though there are used so-called shackles or snap-link fasteners for coupling eye-members or chain links or the like in the anchor cable.

Various suitable load cell means may be used though preferably there is used an electrical effect type load cell wherein the tension is measured by means of a change in an electrical property such as resistance. Any suitable signal transmission means may be used between the load cell and the control system. Conveniently there is used either an electrical cable means or an electromagnetic radiation transmitter and receiver means.

Any suitable control system device may be used including a microcomputer or a dedicated device with hard wired control logic. Conveniently there is used a device provided with a user interface such as a keyboard or touchscreen especially where more sophisticated control is desired, for example, where it is desired to allow the user to set an alarm-triggering tension which may be lower than the anchor setting tension, for example a tension of between 50% and 95% thereof, or where it is desired to enable the user to make calculations as to desirable anchor tensions to which his anchor should be stressed during the anchoring procedure, or desirable alarm tensions to which his monitoring alarm system should be set.

The processor means may moreover be adapted to receive additional

input signals, for example from a wind-speed measuring device or anemometer and/or a second load cell on a second anchor cable, and may be formed and arranged for comparing anchor cable tension in the (or the first) anchor cable with an expected anchor cable tension derived from the wind resistance of the vessel in such a way that a cable tension lower than that anticipated on the basis of the known wind resistance of the vessel would be indicative of anchor dragging, or comparing anchor cable tensions between different anchor cables to detect any imbalances.

Any suitable warning signal display means may be used including audio and/or visual display means such as alarm horns, bells, flashing lights, and/or simply a visual display unit (VDU) such as a liquid crystal display (LCD) or light emitting diode (LED) display.

Further preferred features and advantages of the invention will appear from the following description given by way of examples with reference to the accompanying drawings, in which:

Figure 7: is a diagram showing general layouts of the anchor alarm system

Figure 8: shows illustrative designs of load cells suitable for the anchor alarm system

Figure 9: shows the circuit of a Wheatstone bridge suitable for use with resistance strain gauges

Figure 10: shows an illustrative block diagram of electrical circuitry suitable for the load cell and control box of the anchor alarm system

EXAMPLE 1

One general embodiment of the invention, which has been constructed and tested, is illustrated by reference to Figure 7(A), in which: a metal link, 1, henceforth called a LOAD-LINK, is connected at one end to a strong point on the deck of a vessel, 2, and at the other end to the anchor cable, 3. For chain cable, the connections are most conveniently made using U-form shackles, 4, 4', so that the LOAD-LINK, 1, takes the full load on the anchor cable when the cable is tensioned. That is, the load on the anchor cable is transmitted from the anchor, 5, via the section of anchor cable, 3, which runs over the bow roller, 6, through the LOAD-LINK, 1, to the strong-point, 2, which is a part of the deck of the yacht. The LOAD-LINK conveniently comprises a metal bar section made from either stainless steel or marine grade aluminium alloy to which is

attached four electrical resistance strain gauges. The four strain gauges are connected together to form a Wheatstone Bridge and can thereby be used to measure the extension of the LOAD-LINK and the tension to which it is subjected, the tension being proportional to the extension of the measuring section of the LOAD-LINK. It will be appreciated that the dimensions of the critical part of the LOAD-LINK, that is the part of the link which bears the strain gauges, must be chosen so that the maximum strain to which the LOAD-LINK is likely to be subjected is substantially less than the strain at the yield point of the material of the LOAD-LINK. The yield points for stainless steel and aluminium occur at strains (defined as the fractional extension of a material) of approximately 0.2%. It will also be appreciated that there are a number of different ways in which the LOAD-LINK may be mechanically connected to take the full load on the anchor cable. The LOAD-LINK may be coupled either directly between a strong point on the deck of the yacht and the anchor cable as shown in Figure 7, or it may simply be coupled between different parts of a single section of the anchor cable by mechanically short circuiting a loop of anchor cable. Alternatively the LOAD-LINK may be connected between separate sections of the anchor cable, to form what amounts to a long link

in the cable, and may consequently be below water and even connected directly to the anchor itself. Any suitable mechanical coupling of the LOAD-LINK to the anchor cable may be used including, rope, chain, shackles, clamping means and releasable fasteners. When using chain cable, shackles or releasable snap fasteners as shown in Figure 1 are the most convenient connectors; when connecting to warp, rope tied to the warp by a knot known as a prussic hitch gives the simplest non-slip connection.

Referring again to Figure 7(A), the LOAD-LINK is connected by an electric cable, 7, to suitable electronics housed in a remotely situated CONTROL BOX, 8, which comprises the said control system of the invention. The LOAD-LINK and CONTROL BOX receive their power from the electrical battery, 9. Typically the battery used to power the system will be the ships battery, but any rechargable battery with a capacity of preferably not less than ten ampere hours is suitable.

An alternative embodiment of the invention may be explained by reference to Figure 7(B) wherein, the LOAD-LINK contains a small radiofrequency transmitter, 10, and the control box contains a corresponding radiofrequency receiver, 11, so that the signal

proportional to the tension on the LOAD LINK can be transmitted by radio between the LOAD-LINK and the CONTROL BOX. In this embodiment, the LOAD-LINK is still connected to the ships battery or suitable alternative, 9, but the CONTROL BOX, 8, becomes free-standing with its own small battery, 12, as power supply.

The CONTROL BOX, whether wired to the LOAD-LINK or freestanding, is designed to accept a signal from the LOAD-LINK corresponding to the tension experienced by the LOAD-LINK and to output this tension on an appropriate VDU display such as an LCD or an LED display in appropriate units such as kilograms weight. While the LOAD-LINK would normally be situated on the deck of the vessel, other configurations of the system where the LOAD-LINK is below water and even at the anchor itself, are not excluded from the scope of the invention. The CONTROL BOX would normally be in the cockpit area of a yacht during the anchoring procedure and would be transferred to the navigation area below deck when it was to be used for subsequent monitoring of the anchoring situation of the yacht. The inclusion of a radio link between the LOAD-LINK and the CONTROL BOX is particularly convenient when it is desired to use the CONTROL BOX at different locations on board a vessel.

EXAMPLE 2

Several LOAD-LINKs have been constructed and tested. Illustrative examples are described in detail by reference to Figure 8. It is to be understood that the designs shown in Figure 8 are simply illustrative of the principle of the LOAD-LINK and that many other configurations of the basic unit, including both its shape and dimensions, are possible.

Figure 8(A) shows a LOAD-LINK which may conveniently be fabricated from marine grade stainless steel (grade 316 stainless steel), comprising a central cylindrical bar, 13, whose diameter for loadings up to 1000 kg is 8 mm, welded to two collars 14 and 14', although other methods of attachment such as threading the bar and collars are not excluded. It will be appreciated that the attachment of the bar, 13, to the collars, 14, 14', must be strong enough to withstand a force of at least 1000 kg. The collars 14 and 14' are conveniently of cylindrical cross section having a diameter of 20 mm to 25 mm and having spade ends 15 and 15' containing holes 16 and 16' drilled to 9 mm diameter to accomodate standard 8mm shackles useful for connecting the LOAD-LINK to the anchor cable.

The central bar, 13, has four strain gauges attached to it. Two of the strain gauges, denoted, 17 and 17', are positioned along the axis of the bar and are therefore stretched when the bar is subject to load. The other two gauges, denoted 18 and 18', are positioned at right angles to the first pair, being fitted around the bar; they contract slightly when the bar is subject to load. The ratio of the radial contraction to the axial extension of a bar under tension is known as the Poisson Ratio, and has a value of about 0.3 for most metals. There are available units containing pairs of strain gauges, where the two associated gauges are mounted at right angles to one another. Conveniently two such units are used perform the same function as four individual strain gauges, one pair comprising gauges 17, 18, and the other comprising gauges 17', 18'. Whether using individual gauges or paired gauges, the four component gauges are connected together in the form of a Wheatstone bridge. The Wheatstone bridge is connected to the CONTROL BOX by means of a sheathed cable, 7, whose diameter is conveniently in the range of 4 mm to 7 mm, and whose length is in the range 10 m to 15 m. Sheathing is desirable for mechanical protection of the wiring, and for the elimination of electrical interference, and is connected electrically to the bar 13, by means of a clamp 19, which also

serves to anchor the cable to the bar so that it cannot readily be pulled out during rugged use. In order to isolate the strain gauges and the connections from possible ingress of water, the metal parts of the LOAD-LINK along with the strain gauges, any associated electronics such as a head amplifier and/or a radiofrequency transmitter, and the last few cm of cable are enclosed within a rigid metal or plastic tube, 20, which fits loosely on to the collars 14 and 14' of Figure 2(A), and the space within the tube is filled with a self hardening silicone rubber, 21, subsequent to the assembly of the rest of the LOAD-LINK.

Figure 8(B) shows LOAD-LINK which may conveniently be fabricated from a single piece of cylindrical aluminium alloy bar stock, 22, (corresponding to parts 13, 14, and 14' of Figure 2(A)).
By way of example, for loadings up to 1000 kg, this bar has a diameter of 19 mm and contains a 9 mm wide through-milled slot, 23, which leaves a remaining cross section of metal amounting to about 150 sq mm. Additionally the bar has spade ends, 15 and 15' bearing 9 mm diameter holes, 16 and 16'in order to accomodate standard 8mm shackles useful for connecting the LOAD-LINK to the anchor cable. An additional angled hole, 24, is drilled to connect the inside of the slot, 23, to the outside of the bar,

the diameter of the hole being just larger than the diameter of the connecting cable, 7, which passes through it. The cable is retained at its inner end by means of a compression sleeve, 25, which is just too large to pass through the hole, 24. The four strain gauges are mounted inside the slot, two of the four strain gauges 17, 17' being mounted axially, the other two, 18, 18' transversely; the four gauges are connnected to form a Wheatstone Bridge. Conveniently the four single strain gauges may be substituted by a pair of twin gauges. The bar is enclosed within a rigid metal or plastic tube, 20, and to ensure exclusion of water, the internal space within the tube is filled with silicone rubber sealant, 21.

It has been noted in practice that the design shown in Figure 8(A) is somewhat sensitive to bending of the 8 mm central bar, while the design shown in Figure 8(B) is somewhat sensitive to radial compression of the metal comprising the two sides of the slot. These two designs are intended to be illustrative and other cross sections for the central part of the LOAD-LINK are not excluded, in particular sections specifically designed to minimze the effects of bending and radial compression, such as cruciform or H-form sections.

The operation of the LOAD-LINK and its associated strain gauges is explained as follows. The extension of the central section of the LOAD-LINK which bears the strain gauges (i.e.bar 13 of figure 8(A) or the slotted section of bar 22 in Figure 8(B)) under a given load may be calculated from its cross section and the elastic modulus of the metal of the bar. The elastic modulus of stainless steel is known to have a value of about $1.8x10^6$ kg per square centimeter, and that of aluminium alloys about $0.6x10^5$ kg per square centimeter. Thus under a load of 1000 kg an 8 mm diameter stainless steel bar, whose cross sectional area is 0.50 sq cm will stretch by the fraction $\delta L/L$ (known as the "strain" experienced by the bar) which is given by:

$$\text{Strain} = \delta L/L = 1000/(0.5 \times 1.8x10^6) = 1.1x10^{-3} \approx 0.1\%$$

Likewise under a load of 1000 kg an aluminium bar with a cross sectional area of 1.50 sq cm having an elastic modulus about one third that of stainless steel will stretch by the same proportion. In both cases, with a Poisson ratio of 0.3, there will occur a transverse shrinkage of 0.03%. It should be noted that a strain of 0.1% is about half the strain at the yield points of stainless steel and aluminium, and therefore that loads of 1000 kg can be applied without hysteresis. For LOAD-LINKs

that are required to take maximum loads greater than 1000 kg, cross sections proportionately larger than those suggested above will be required.

For proper operation, it is desirable that the anchor alarm system should be able to resolve loads down to about 1 kg. Thus, according to the above calculation, it is necessary to be able to measure axial strain to about 1 part per million (ppm). Suitable strain gauges, 17, 17', 18, 18', which have been used in an experimental prototype, are obtainable in the UK from RS Components Ltd. with a catalogue number RS 632-168. These gauges have resistances of 120 ohm and dimensions of 8mm by 2mm. Resistance strain gauges are characterised by a so-called "Gauge Factor" which is defined as the ratio of the fractional change in the gauge resistance, $\delta R/R$, to the fractional change in the length of the gauge, $\delta L/L$. Gauges of the type described above have a gauge factor of about 2.

It has been stated above that the four gauges are connected in the form of a Wheatstone bridge. The precise configuration of the gauges in the Wheatstone Bridge is shown in Figure 9. Thus the resistance of the gauges 17 and 17', which stretch, will increase

by about 2 ppm per kg load, while the resistance of the gauges 18 and 18', which contract, will decrease by about 0.6 ppm per kg load. These changes in resistance, when the four gauges are connected as shown in Figure 9, will generate an off-balance emf across the points A and C amounting to about 2.6 ppm of the voltage applied across the points B and D per kg load. The main considerations in choosing the voltage to be applied across points B and D of the bridge are (i) that too high a voltage causes self heating and consequent instability of the LOAD-LINK, and (ii) that too low a voltage provides too low an off-balance signal which can introduce electrical noise and other forms of instability. Experience shows that self heating can be avoided if the bridge voltage is no more than 4 V. The inclusion of a small head amplifier within the LOAD-LINK itself can enable lower bridge voltages to be used without incurring noise and instability, and advantageously reduces the current drain on the battery.

EXAMPLE 3

The elements of a basic CONTROL BOX (Figure 7 component 8) for the anchor alarm system may be described with reference to Figure 10 which is intended to illustrate how the main objectives of the invention can be achieved. The requirments for a basic control

box are (i) to measure and display the current load or tension on an anchor cable, (ii) to store and display the maximum load or tension which has been experienced since the start of the anchoring procedure (the anchor-setting tension), and (iii) to alert crew by means of an alarm (the warning signal output means), when the current value of the anchor load or tension exceeds the maximum load experienced during anchoring or some other, normally lower, preset load. In Figure 10 three possible arrangements of the electronic circuitry of the LOAD-LINK and CONTROL BOX combination are shown. Referring to Figure 4(A), the LOAD-LINK, 1, contains the four strain gauges mounted in a Wheatstone bridge, 26. The LOAD-LINK is connected to the CONTROL BOX by a four cored cable, 7, the four connections being made to the points A, B, C, and D of the Wheatstone bridge (Figure 9). The bridge operating voltage is supplied to points B and D, while the output is taken from points A and C. The output from the bridge passes first to an amplifier, 27, which amplifies the off-balance voltage from the bridge by a factor in the range 100 to 10,000 to enable it to be handled by the other electronic circuits in the CONTROL BOX. The amplifier may alternatively be incorporated as a component within the LOAD-LINK, as shown in Figure 10(B), in which case the connecting cable, 7, from the

LOAD-LINK to the CONTROL BOX may conveniently be a three- rather than a four-cored cable. In a further embodiment of the LOAD-LINK/CONTROL BOX combination illustrated in Figure 10(C), the LOAD-LINK contains a head amplifier, 27, and in addition a small short-range radiofrequency transmitter, 10, of the type which is now permitted without specific Home Office Licence. The CONTROL BOX then contains a matching receiver, 11. In this embodiment the LOAD-LINK will be supplied with power through a two cored cable, 7, which is no longer connected to the CONTROL BOX, the latter being free standing, and containing its own small battery (Figure 7 component 12).

For each embodiment of the LOAD-LINK/CONTROL BOX combination, as shown in Figure 10, the signal from the bridge, suitably amplified, and if appropriate transmitted by radio from the LOAD-LINK to the CONTROL BOX, passes to a current-load-register, 29, with its associated display, 30. The preferred type of displays being back-lit LCDs, although other types of display such as LED displays are not excluded. The current-load-value can be reset to zero by pressing the current-load-reset switch or button, 31. Preferably the switches are waterproof press button activated microswitches which are widely available, and in what follows the word button is to be taken as meaning one such

switch. The signal from the current-load-register is passed to the maximum-load-register, 32, which retains or memorises the maximum value of the load which has been experienced since the maximum-load-reset button, 33, was last pressed. This would normally be done at the start of the anchoring procedure. Pressing the maximum-load-reset button, 33, will set the maximum-load-value to the value of the current load, following which it will resume its function of recording the maximum value of the load. The value of the maximum load is displayed on a maximum-load-display, 34. The alarm section of the control box comprises an alarm-register, 35, and display, 36, along with control buttons 37, 38, and 39, and a comparator, 40. The function of the comparator, 40, is to compare the value in the alarm-register, 35, with that in the current-load-register, 29, and to signal when the latter value exceeds the value held in the alarm-register, so that an audible, visual, or alternative form of alarm, 41, is immediately activated. The value held in the alarm-register can be preset in two ways: (i) it can be set equal to the value in the maximum-load-register by pressing the maximum-load-transfer button 37, or it can be adjusted to some other value by pressing the alarm-load-adjust button (or buttons), 38. The alarm load may also be reset to a default value, for example

999 kg, by pressing the alarm-load-reset button 39. Finally if the alarm is activated by the current-load-value rising to a value above the alarm-load, the alarm will continue to operate even when the current-load has fallen below the alarm-load, although it can then be switched off by pressing the alarm-off button 42. As a safety measure, the alarm cannot be switched off if the current-load continues to exceed the alarm-load. In such circumstances the alarm-load must first be reset to a higher value than the current-load.

It will be appreciated that there are many different arrangements of the control units, displays and control buttons or switches which can achieve the same objectives as the above described arrangement. For example the three displays, 30, 34, and 36 may be incorporated into one or two display units with suitable toggle switching to enable the load value(s) in the specific register(s) to be displayed. It is also envisaged that the number of buttons can be reduced by employing combinations of buttons pressed simultaneously or in quick succession, rather than single buttons to effect the various operations performed by 31, 33, 37, 38, 39, and 42.

EXAMPLE 4

The stability and sensitivity of LOAD-LINKs constructed according to Example 2 and of a CONTROL BOX constructed according to Example 3 were determined by static testing. To check the stability of the CONTROL BOX, constructed according to Figure 10(A), a cruciform arrangement of 120 ohm resistors was used to provide an equivalent resistance profile to the normal Wheatstone bridge but giving zero voltage output. Using this replacement for the normal Wheatstone bridge it was established that there was no noticeable drift in the electronics of the CONTROL BOX.

Several LOAD-LINKs constructed according to Figure 8(A) were tested using the CONTROL BOX under static conditions with a 92 kg load with bridge voltages between 9 and 12 V. The LOAD-LINKS showed moderate stability over a period of several days, equivalent to a load variation of about plus or minus 20kg. In the course of testing, it was noted that the units became warm and this heating undoubtedly contributed to instability. Lower bridge voltages were used subsequently. The absolute sensitivity of the LOAD-LINK was 1.9 µV/V-kg, which is close to the specified sensitivity of 2.0 µV/V-kg, implying a fractional extension of the central bar of the LOAD-LINK of about 1 ppm/kg.

Another LOAD-LINK of the same design was tested statically with 6 V across the Wheatstone bridge by repeated loading and unloading using loads of 170 kg and 260 kg. The bridge output was measured by the CONTROL BOX, and simultaneously recorded by a Servoscribe potentiometric recorder type RE541 set to a full scale deflection range of 1, 2 or 5 mV. The LOAD-LINK showed good stability over both the short and long term and gave a sensitivity of 1.6 μV/V-kg. However difficulty was experienced in achieving good attachment of the strain gauges to the 8 mm diameter stainless steel bar (Figure 8 part 13).

An aluminium LOAD-LINK constructed according to Figure 8(B) was tested in like manner using 6 V across the Wheatstone bridge. The sensitivity of the LOAD-LINK was 1.7 μV/V-kg, and the LOAD-LINK showed excellent short- and long-term stability with a drift equivalent to less than 10 kg over many days. Further experiments with 4 V bridge voltage provided similar results.

It was concluded that the design of the aluminium LOAD-LINKs shown in Figure 8(B) was preferable to that of the stainless steel versions shown in Figure 8(A), and that bridge voltages of not more than 6 V should be used.

EXAMPLE 5

The invention in the form described in Examples 1 to 3 using a stainless steel LOAD-LINK shown in Figure 8(A) and a CONTROL BOX of the type illustrated in Figure 10(A), was tested on board a 11 metre sailing yacht of a type known as the Hustler 35. The yacht, weighing about 6000kg, was equipped with a 20 hp Volvo MD2 engine, a 15 kg CQR anchor, 25 metres of 5/16" (8 mm) chain cable plus 40 metres of 25 mm diameter nylon warp. In the course of testing the anchor alarm system, it was found that an additional stage had to be included in the anchoring procedure in order to achieve sufficient tension in the anchor cable to be sure of withstanding extreme conditions. This final stage was as follows:

(vii) Jerk Test: the vessel is motored forwards and then in reverse so that it comes to a jerk stop as the anchor cable tightens. Tensions up to 500 kg are thereby readily be achieved.

The anchor alarm system was deployed in the following way:

(a) At some time before setting the anchor at stage (v) of the anchoring procedure, the CONTROL BOX was placed in the cockpit and one end of the LOAD-LINK attached to a strong cleat on the foredeck. The anchor alarm system was connected to the power supply and the three registers reset; that is the current

load was set to zero, the maximum load was reset to the current load, and the alarm load was set to a high default value.

(b) Just before stage (v) and after the required length of anchor cable has been deployed the other end of the LOAD-LINK was connected to the anchor cable so that it would subsequently take the full load on the cable. Since we always deployed the entire length of chain plus 10 metres of warp, the LOAD-LINK was tied to the the anchor warp with 10 mm diameter rope using a prussic hitch.

(c) During stage (v), with the CONTROL BOX in the cockpit, the current load on the cable, and the maximum load experienced since the start of anchoring was continually monitored by the helmsman. The maximum loadings achieved in stages (vi) and (vii) were noted. Subsequently the alarm-load was set at an appropriate value, and the CONTROL BOX moved below deck to the navigation area.

Over a period of approximately two weeks results were obtained which are summarised in Table 7.

TABLE 7

Anchorage	Type of bottom	Depth (metres)	Force (kg)	Notes
Oronsäy (Skye)	Sand	5	E-90	(1)
			J-500	(2)
L. Turmaig (L. Ewe)	Not known	5	J-250	
			J-450	(3)
L. Ewe (temporary)	Sand	3	J-100	
Tanera Mor West	Weed	7	E-30 dragged	
Tanera Mor East	Weed & sand	7	J-150	
	(wind overnight 25 kn)		J-250	(3)
Badcall Bay	Soft mud, hard below	7	E-60 dragged	
	allowed to settle 2 hrs		J-150	(4)
Shieldaig	Sand	7	J-200	
Muck	Sand	6	J-200	

Notes:
(1) E means pulled steadily with engine at maximum revs.
(2) J means achieved with a jerk stop.
(3) Here the holding was re-tested before weighing anchor in the morning.
(4) In Badcall Bay a crew member dived on the anchor which was embedded in mud. The mud was soft down to about 0.3 metres then hard below that. Overnight wind was up to 30 knots.

From the results shown in Table 7 a number of conclusions may be drawn. When an anchor is dragging through weed its holding power is very low and in the region of about 20 to 30 kg. Dragging in soft mud gives a somewhat better hold of about 60 kg. When anchoring the maximum pull which can be exerted by a 20 hp engine at full throttle is around 90 kg which, for an 11 metre yacht, is inadequate if it is anticipated that subsequent wind strength will reach more than 25 knots. To achieve a sufficient

tension on the cable to be sure that the anchor will hold against winds of 40 or 50 knots, it is necessary to use the jerk-stop method of stressing the anchor cable.

Notwithstanding the above it may be noted, referring to Figure 6, that with 25 metres of 5/16" (8 mm) chain weighing 1.5 kg/m and 10 metres of warp, our chain would have lifted off the bottom in 7 metres of water at a load of about 120 kg. Had we used 3/8" (9.5 mm) chain, the lift off load would have been about 200 kg. It is evident that the chain component of our present anchor cable is inadequate to ensure good holding under extreme conditions, in repect of both the chain length and chain weight.

EXAMPLE 6

The following additional embodiments of the anchor alarm system are envisaged.

(1) Anchor alarm system coupled to wind speed measuring device. Generally for an anchored vessel which is headed directly into the wind, the anchor load will be close to that calculated from the wind speed, although there will be short term deviations due to fluctuations in the wind speed and direction, and in the

attitude of the vessel to its anchor cable. Nevertheless over a period of time the variations should be equalised and the mean anchor load should approximate to the mean wind resistance. If the vessel's anchor were to drag the load on the cable would immediately drop. Accordingly, detection of a mean anchor load which was substantially less than the load expected on the basis of wind force would indicate dragging of the anchor. We envisage a further aspect of the invention whereby, the signal from an anemometer is led to the CONTROL BOX which has facilities for calculating the wind resistance of the vessel and comparing this to the anchor cable loading, both being averaged over a sufficient period of time (for example one to five minutes), so that an alarm is activated whenever the anchor cable load becomes significantly less than the calculated wind resistance.

(2) Anchor alarm system integral with windlass or samson post. With larger vessels it becomes inconvenient to attach a LOAD-LINK to the anchor cable which will generally be led over an anchor winch, windlass or gipsy, and then through a hawse pipe to the chain locker. A further embodiment of the invention envisages that the load cell of the anchor alarm system is incorporated within the said anchor winch, windlass or gipsy so as to measure the tension on the anchor cable as it passes over the winch,

windlass of gipsy. Thus, for example, strain gauges could be attached to the spindle of an anchor windlass to measure the torsion of the spindle under load. Alternatively, where the anchor cable is ultimately held by a strong cleat or samson post, the load cell may be incorporated within the cleat or samson post. For example strain gauges may be incorporated within tha samson post to detect slight bending of the post. With such arrangements the anchor alarm system now becomes an integral part of the vessel.

CLAIMS

1. An anchor alarm system for use in monitoring the anchorage condition of a vessel, which system comprises load cell means provided with mechanical coupling means for connection of the load cell means, in use of the system, in-line with an anchor cable means of a vessel, said load cell means being provided with signal transmission means for transmissison, in use of the system, of a signal related to the tension to which said load cell means is subjected, to a control system having a processor means, memory means, and warning signal output means, said processor means being formed and arranged for receiving anchor cable tension signals from said load cell means, storing data in said memory means corresponding to a maximum anchor cable tension signal corresponding in turn to an anchor-setting tension on said anchor cable, in a set-up mode of the control system, comparing subsequent anchor cable tension signals with data stored in said memory means so as to detect at least anchor cable tensions greater than said anchor-setting tension or some lesser preset alarm-triggering tension, in a monitoring mode of the control system, and driving said warning signal output means in

response to detection of such greater anchor cable tensions, in an alarm mode of the control system.

(2) A method of monitoring the anchorage condition of a vessel comprising the steps of recording an initial maximum anchor cable tension corresponding to an anchor-setting tension, monitoring anchor cable tension thereafter and comparing it with said anchor-setting tension or some lesser preset tension, and generating a warning signal output at least when the anchor cable tension exceeds said anchor-setting tension or alternate preset alarm-triggering tension.

3. An alarm system as in claim 1 where the expression anchor cable indicates any flexible elongate member used for connecting a vessel to its anchor including chain and rope and any combination thereof.

4. An alarm system as in Claim 1 where the load cell is coupled between the vessel and one end of the anchor cable, or between the vessel and some point within the length of the anchor cable.

5. An alarm system as in Claim 1 where the load cell is coupled directly in-line with the anchor cable, for example between separate sections of the anchor cable, or between different parts

of a single section of the anchor cable by mechanically short circuiting a loop of anchor cable.

6. An alarm system as in Claims 1, 4 and 5, where the load cell is situated on the foredeck of a yacht.

7. An alarm system as in Claims 1 and 5, where the load cell is situated below water.

8. An alarm system as in Claim 7, where one end of the load cell is connected to the anchor and the other end to the anchor cable.

9. An alarm system as in Claim 1 where the said load cell is coupled to the anchor cable by, rope, chain, clamping means, releasable fasteners or any combination thereof.

10. An alarm system as in Claim 1 where the load cell means comprises an electrical effect type load cell wherein the anchor cable tension is measured by means of a change in an electrical property such as resistance.

11. An alarm system as in Claim 10, where the active members of the load cell are electrical resistance strain gauges arranged as a Wheatstone bridge or part thereof, which is powered by an electrical power source, and whose output is proportionate to the tension experienced by the said load cell.

12. An alarm system as in Claim 1 where the transmission means between the load cell and the control system is an electrical cable means.

13. An alarm system as in Claim 1 where the transmission means between the load cell and the control system is an electromagnetic radiation transmitter and receiver means.

14. An alarm system as in Claim 1 where the control system device is a microcomputer.

15. An alarm system as in Claim 1 where the control system device is a dedicated device with hard wired control logic.

16. An alarm system as in Claim 1 where the processor means is adapted to receive input signals from a wind velocity measuring means, and is additionally formed and arranged for comparing anchor cable tension with an expected anchor cable tension derived from the wind resistance of the vessel, so as to detect anchor cable tensions lower than the said expected anchor cable tension, and driving the (or an additional) warning signal output in response to detection of such lower anchor cable tensions.

17. An alarm system as in Claim 1 where the processor means is

additionally formed and arranged for receiving anchor cable data from additional anchor cable means, and for comparing anchor cable tensions between different anchor cables.

18. An alarm system as in Claim 1, where the load cell means is incorporated in an anchor winch, windlass or gipsy.

19. An alarm system as in Claim 1, where the load cell means is incorporated in an anchor cable mooring cleat or samson post.

20. An alarm system as in Claims 1 and 11 where the strain gauge means are incorporated in an anchor winch, windlass or gipsy.

21. An alarm system as in Claims 1 and 11 where the strain gauge means are incorporated in an anchor cable mooring cleat or samson post.

22. An alarm system as in Claim 1 where the warning signal output means comprises audio and/or visual display means such as alarm horns, bells, flashing lights, and/or simply a visual display unit (VDU) such as a liquid crystal display (LCD) or light emitting diode (LED) display.

23. An alarm system substantially as described herein with reference to Figures 7-10 of the accompanying drawings.

24. A method of monitoring the anchorage condition of a vessel as in Claim 2, using the anchor alarm system of Claims 1, and 3-23.

25. A method of monitoring the anchorage condition as in Claim 2 of a vessel whose overall length is between 6 and 20 metres.

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Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

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Documents considered relevant following a search in respect of claims ALL

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 1526343 (IMODCO) Page 2 line 89 onwards	1-3, 5, 8-11, 13, 14
X	GB 1351227 (SHELL) Whole document is relevant	1-3, 13
X	GB 1241776 (GLOBAL) Note page 1 lines 25-54, Figure 1, page 5 line 32 onwards	2, 6
X	US 3810081 (RINNGER) See Figure 2	2

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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